

10/567174

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
15 December 2005 (15.12.2005)

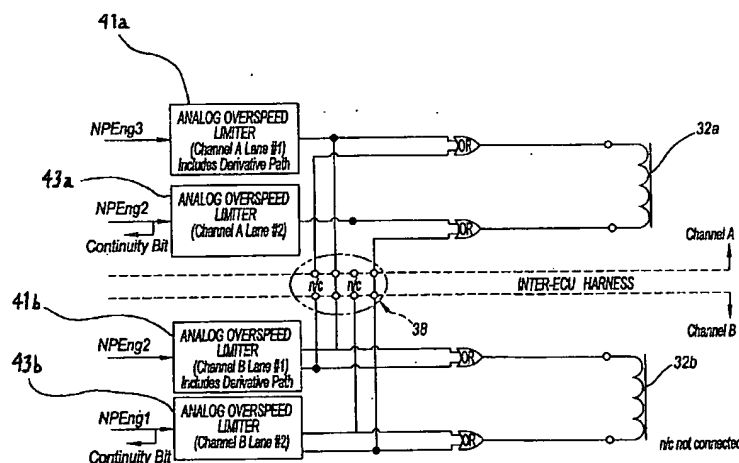
PCT

(10) International Publication Number
WO 2005/119012 A1

- (51) International Patent Classification⁷: **F01D 21/02**,
F02C 9/28, 9/46
- (21) International Application Number:
PCT/US2005/019699
- (22) International Filing Date: 3 June 2005 (03.06.2005)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
60/576,779 3 June 2004 (03.06.2004) US
- (71) Applicant (for all designated States except US):
GOODRICH PUMP & ENGINE CONTROL SYSTEMS, INC. [US/US]; Box 330651, Charter Oak Boulevard, West Hartford, CT 06133-0651 (US).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **ROGERS, David, M.** [US/US]; 51 Oakengates, Avon, CT 06001 (US). **ZAGRANSKI, Raymond, D.** [US/US]; 50 Cricket Lane, Somers, CT 06071 (US). **MANNARINO, Giovanni** [CA/CA]; 153 Vivian, Town Of Mount Royal, Quebec (CA). **REID, Matthew, Robert** [CA/—]; 1765 des Erables, St. Bruno, Quebec, J3V4P2 (CA).
- (74) Agent: **SILVIA, David, J.**; Edwards & Angell, LLP, P.O. Box 55874, Boston, MA 02205 (US).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: OVERSPEED LIMITER FOR TURBOSHAFT ENGINES



(57) Abstract: The subject invention is directed to a control system for a turboshaft engine utilized in a helicopter which includes means for providing minimum fuel flow to the engine when an overspeed condition is detected at a relatively low altitude (e.g., below 10,000 feet), and means for shutting off fuel flow to the engine, and thus shutting down the engine, when an overspeed, loss of load condition is detected at a relatively high altitude (e.g. above 10,000 feet). The overspeed, loss of load condition is detected along two different engine speed signal paths, including a derivative path and a non-derivative path.

WO 2005/119012 A1



Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

OVERSPEED LIMITER FOR TURBOSHAFT ENGINES

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application Serial No. 60/576,779, filed June 3, 2004, the disclosure of which is herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The subject invention is directed to control systems for gas turbine engines, and more particularly, to power turbine overspeed limiters for turboshaft engines used in helicopters.

2. Background of the Related Art

[0003] Overspeed limiters for gas turbine engines are known in the prior art. The function of an overspeed limiter is to prevent the occurrence of excessive turbine speeds by limiting fuel flow to the engine. Examples of prior art overspeed limiters are described in U.S. Patent No. 4,302,931 to White et al. and U.S. Patent No. 4,578,945 to Peck et al., the disclosures of which are herein incorporated by reference in their entireties.

[0004] Turboshaft engines installed on helicopters require a unique power turbine overspeed limiter. It needs to protect the engine against a loss of load and potential power turbine overspeed, and preclude false overspeed limiter trips. False

limiter trips significantly reduce engine power, and can occur when a pilot is flying the helicopter aggressively.

[0005] In the past, these requirements have been addressed by providing overspeed limiters that do not completely shutdown the engine when an overspeed condition is detected, but instead trip to a minimum fuel flow condition. Other prior art systems shutdown the engine when an overspeed condition is detected, and then restart the engine using an auto-relight feature.

[0006] In modern low inertia gas turbines, minimum fuel flow systems are not capable of containing loss-of-load power turbine overspeeds at high altitude, because the horsepower requirements are too significant. Auto-relight systems are not guaranteed to restart an engine under all operating conditions, especially when the primary engine control system has failed and the engine is operating with a simple manual backup control.

[0007] Accordingly, there is a need in the art for an overspeed limiter for a turboshaft engine that is capable of effectively handling power turbine overspeeds at both high and low altitude.

SUMMARY OF THE INVENTION

[0008] The subject invention is directed to a control system for a turboshaft engine utilized in a helicopter which includes means for providing minimum fuel flow to the engine when an overspeed condition is detected at a relatively low altitude (e.g., below 10,000 feet), and means for shutting off fuel flow to the engine, and thus shutting down the engine, when an overspeed, loss of load condition is detected at a relatively high altitude (e.g. above 10,000 feet), provided that the overspeed, loss of load

condition is detected along two different engine speed signal paths, including a derivative path and a non-derivative path.

[0009] The subject invention is also directed to a control system for a turboshaft engine which provides a desired minimum fuel flow to the engine when an overspeed condition is detected and when the engine is operating in a first operating range and shuts off fuel flow to the engine when an overspeed condition is detected and the engine is operating in a second operating range. It is presently envisioned that an overspeed condition is detected based on at least one of, for example, a power turbine speed signal, a gas generator speed signal and main rotor speed signal.

[00010] Preferably, in the first operating range the engine is operating at a relatively low altitude and in the second operating range the engine is operating at a relatively high altitude. In a representative system, the relatively low altitude includes 0 to 10,000 feet above sea level and the relatively high altitude exceeds 10,000 feet above sea level, for example.

[00011] In a preferred embodiment, an overspeed condition is detected along two different control logic paths, a first logic path which includes derivative and non-derivative control logic and a second logic path which includes non-derivative logic (e.g. proportional logic).

[00012] It is envisioned that the control system further includes a hardware latch having reset logic associated therewith. Additionally, the control system can include software test interfaces for testing the performance of the control system.

[00013] In a representative embodiment, a minimum fuel flow is provided to the engine when an overspeed condition is detected through a first solenoid valve and the

fuel flow to the engine is shut off when an overspeed condition is detected by a second solenoid valve.

[00014] In preferred embodiments the control system is a dual channel system having an interchannel communication means for ensuring that a fault in one channel of the system will not shut down the control system or impact the systems ability to limit engine overspeed.

[00015] The present invention is also directed to a control system for a turboshaft engine which includes a mechanism for shutting off fuel flow to the engine when an overspeed condition is detected, wherein the overspeed condition is detected by first and second control logic paths. It is envisioned that the first control logic path includes a derivative path and a non-derivative path and the second control logic path includes a non-derivative path. Preferably, the control system includes a device for disabling the fuel shut-off mechanism when the engine is operating below an altitude of 10,000 feet.

[00016] The present disclosure is also directed to a control system for a turboshaft engine which includes a mechanism for providing a minimum fuel flow to the engine when an overspeed condition is detected in a first operating range; and a mechanism for shutting off fuel flow to the engine when an overspeed condition is detected in a second operating range. It is preferred that the overspeed condition is detected along two different engine speed signal paths, including a derivative path and a non-derivative path.

[00017] Preferably, in the first operating range the engine is operating at a relatively low altitude and in the second operating range the engine is operating at a relatively high altitude. In a representative system, the relatively low altitude includes

0 to 10,000 feet above sea level and the relatively high altitude exceeds 10,000 feet above sea level, for example.

[00018] In a preferred embodiment, an overspeed condition is detected along two different control logic paths, a first logic path which includes derivative and non-derivative control logic and a second logic path which includes non-derivative logic (e.g. proportional logic).

[00019] It is envisioned that the control system further includes a hardware latch having reset logic associated therewith. Additionally, the control system can include software test interfaces for testing the performance of the control system.

[00020] In a representative embodiment, a minimum fuel flow is provided to the engine when an overspeed condition is detected through a first solenoid valve and the fuel flow to the engine is shut off when an overspeed condition is detected by a second solenoid valve.

[00021] In preferred embodiments the control system is a dual channel system having an interchannel communication means for ensuring that a fault in one channel of the system will not shut down the control system or impact the systems ability to limit engine overspeed.

[00022] The present disclosure is also directed to a method for limiting turboshaft engine overspeed that includes measuring at least one engine speed parameter; sensing the altitude at which the engine is operating and determining whether an overspeed condition exists based on the measured speed parameter. The disclosed method uses a control system which includes a first logic path that has derivative and non-derivative control logic and a second logic path that has non-

derivative logic. The inventive method also includes the steps of providing a desired minimum fuel flow to the engine when an overspeed condition is detected by the engine control system when the engine is operating in a first altitude range; and shutting off fuel flow to the engine when an overspeed condition is detected by the engine control system and the engine is operating in a second operating range.

[00023] These and other aspects of the subject invention will become more readily apparent to those having ordinary skill in the art from the following detailed description of the invention taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[00024] So that those having ordinary skill in the art will better understand how to make and use the overspeed limiter system of the subject invention, embodiments thereof will be described below with reference to the drawings wherein:

[00025] Fig. 1 is a schematic diagram of a fuel metering system for a turboshaft engine that employs a preferred embodiment of the overspeed limiter of the subject invention;

[00026] Fig. 2 is a schematic diagram showing representative dual channel hardware voting logic, which will shut down the engine upon detecting an overspeed condition;

[00027] Fig. 2a is a cross-sectional view of a portion of the shaft for the power turbine having three speed probes positioned adjacent thereto for detecting a shaft speed signal;

[00028] Fig. 3 is a schematic diagram showing the engine shut down logic path of Fig. 2, with a hardware latch;

[00029] Fig. 4 is a schematic diagram showing the engine shut down logic path and hardware latch of Fig. 3, with software test interfaces;

[00030] Fig. 5 is a schematic diagram showing the engine shutdown logic path with hardware latch as shown in Fig. 3, combined with a minimum fuel flow logic path;

[00031] Fig. 6 is a schematic diagram showing the combined minimum fuel flow logic path and engine shutdown logic path of Fig. 5, with cross-engine inhibit features; and

[00032] Fig. 7 is a schematic diagram of an alternate embodiment of the two analog overspeed limiter lanes of protection, which include a more precise test of the derivative path in Lane 1, as compared to the software test interfaces of Fig. 4.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[00033] The subject invention overcomes the disadvantages of prior art overspeed limiters used on turboshaft engines in helicopters by preferably providing both a minimum flow overspeed system for low altitude operation (e.g., below 10,000 feet) and a fuel shutoff system for high altitude (e.g., above 10,000 feet) overspeed/loss-of-load conditions.

[00034] The system of the subject invention is uniquely implemented in analog hardware and in the software of the primary engine control unit (ECU) to satisfy all certification standards for: a) the probability of loss of overspeed protection; b) the

probability of a false overspeed trip; and c) the probability of a single failure causing an engine overspeed condition and loss of overspeed protection at the same time.

[00035] Referring now to the drawings, wherein like reference numerals identify similar aspects or features of the subject invention, there is illustrated in Fig. 1 a representative fuel metering system 10 for a turboshaft engine that employs the overspeed limiter of the subject invention. As illustrated in Fig. 1, the fuel metering system 10 includes, among other things, a venturi-type jet inducer 12, which delivers fuel under pressure to a gear pump 14. Gear pump 14 communicates with a high-pressure fuel filter 16. Fuel flows from filter 16 to a fuel metering valve 18 operated by a stepper motor 20 with associated primary gearhead. A feedback device 22 is associated with the metering valve for monitoring the position of the metering valve 18. Feedback device 22 has associated limit switches. Also associated with the metering valve 18 is a combined DC motor, gearhead and clutch set 24, which serves as a backup to the stepper motor 20.

[00036] A pressurizing and leak tight shutoff valve 26 is in fluid communication with fuel metering valve 18. It delivers fuel to the engine by way of a dual coil true minimum flow overspeed solenoid valve 28, which is normally de-energized. A fuel regulator valve 30 also receives filtered fuel from filter 16. Regulator valve 30 communicates with the jet inducer 12 and also communicates with a dual coil overspeed and fuel shutoff solenoid valve 32 that is normally de-energized. Regulator valve 30 is also in fluid communication with fuel metering valve 18. The fuel shutoff solenoid valve 32 is also in fluid communication with the pressurizing shutoff valve 26. As explained in below, the overspeed limiter system of the subject invention controls

the operation of the two dual coil solenoid valves 28 and 32. During normal operating conditions, both solenoid valves 28 and 32 are de-energized.

[00037] Referring now to Fig. 2, there is presented a schematic diagram showing the dual channel hardware voting logic which will shutdown the engine upon detecting an overspeed condition, provided that the overspeed condition is detected along two NP engine signal paths, a first path including a derivative signal path and a second path including a non-derivative engine signal path. In a preferred embodiment, the first path includes both derivative and proportional control logic while the second path includes proportional logic, but does not include derivative logic.

[00038] As illustrated, two NP engine signals (i.e., power turbine speed signals) are brought into each of the two engine control unit (ECU) channels (Channel A and Channel B). As shown, two Analog Overspeed Limiter Lanes of protection are provided for each channel. The logic for these lanes of overspeed protection have been identified by reference numerals 41a/43a for Channel A and reference numerals 41b/43b for Channel B. Each ECU channel includes a respective shutdown coil (32a, 32b) of fuel shutoff solenoid 32.

[00039] Channel A, Analog Overspeed Limiter Lane 1, identified by reference number 41a, includes a derivative path and it receives the engine speed signal NPeng3. Channel A, Analog Overspeed Limiter Lane 2, identified by reference number 43a, includes a non-derivative path (e.g. proportional logic) and it receives the engine speed signal NPeng2. Channel B, Analog Overspeed Limiter Lane 1, identified by reference number 41b, includes a derivative path and it receives the engine speed signal NPeng2. Channel B, Analog Overspeed Limiter Lane 2, identified by reference

number 43b, includes a non-derivative path (e.g., proportional logic) and it receives the engine speed signal NPEng1. Fig. 2a shows the NP speed probe location diagram for engine speed signals NPEng1, NPEng2 and NPEng3, where NPEng3 is shared with the cockpit.

[00040] The hardware voting scheme of Fig. 2 ensures that: a) no single electrical protection system fault will result in a false overspeed trip; and b) no single electrical protection system fault will result in a loss of overspeed protection. The hardware voting scheme depicted in Fig. 2 requires four output pins 38 for interchannel communication. These include two discrete inputs and two discrete outputs. The voting scheme will shutdown the engine under the following votes:

[00041] $\text{NPEng1} + \text{NPEng2} = \text{derivative path} + \text{non-derivative path}$

[00042] $\text{NPEng2} + \text{NPEng3} = \text{derivative path} + \text{non-derivative path}$

[00043] $\text{NPEng1} + \text{NPEng3} = \text{derivative path} + \text{non-derivative path}$

[00044] This voting scheme ensures that under all valid votes, one derivative and one non-derivative engine speed signal path lane detects an overspeed condition. It should be noted that the disclosed control system provides high side and low side drivers to each of solenoids 32a and 32b. As shown, Lane #1 of Channels A and B control the high side drivers for solenoids 32a and 32b and Lane #2 of Channels A and B controls the low side drivers for each of these solenoids.

[00045] Referring Fig. 3, there is illustrated a schematic diagram showing the engine shut down logic path of Fig. 2, with a hardware latch 40 interposed between the two Analog Overspeed Limiter Lanes of Channel A and the shutdown coil 32a of fuel

shutoff solenoid 32. The hardware latch includes two latches 42a, 42b in communication with reset logic and respective field effect transducers (FET) 46a, 46b, which communicate with the shutdown coil 32a of solenoid valve 32. Channel B has an identical hardware latch configuration.

[00046] Referring to Fig. 4, there is illustrated a schematic diagram showing the engine shut down logic path and hardware latch of Fig. 3, with software test interfaces 50 and 52. Interface 50 is associated with input side of the two Analog Overspeed Limiter Lanes of Channel A. Interface 50, for Lane 1 includes a 6.5 second self test window. Software test interface 52 is associated with the latch reset logic. Channel B has an identical software interface associated therewith.

[00047] Referring to Fig. 5, there is illustrated a schematic diagram showing the engine shutdown logic path with hardware latch as shown in Fig. 3, combined with a minimum flow logic path, for the two Analog Overspeed Limiter Lanes of Channel A. In this configuration, Lane 1 includes a derivative path and hysteresis. The combined system of Fig. 5 includes software enable shutdown logic 60 which is selected only when: 1) at high altitude; and 2) the logic detects a loss of load signal (Npdot, Nrdot, Ngc, etc.). In this configuration, the software enable shutdown logic 60 communicates with the shutdown coil 32a of fuel shutoff solenoid 32, while the two Analog Overspeed Limiter Lanes communicate with the shutdown coil 32a and the minimum flow coil 28a of the true minimum flow overspeed solenoid valve 28 through FET's 62a, 62b. Channel B has identical software enable shutdown logic. It should be noted that the disclosed control system provides high side and low side drivers to each of solenoids 28a and 28b. As shown, Lane #1 of Channels A and B control the high side

drivers for solenoids 28a and 28b and Lane #2 of Channels A and B controls the low side drivers for each of these solenoids.

[00048] Referring now to Fig. 6, there is illustrated a schematic diagram showing the combined minimum fuel flow logic path and engine shutdown logic path of Fig. 5, with cross-engine inhibit features, for the two Analog Overspeed Limiter Lanes of Channel A. In this configuration, the software enable shutdown logic communicates with the shutdown coil 32a of solenoid valve 32, as in Fig. 5. The cross-engine inhibit logic 70 runs through nodes that are upstream from the input node for the software enable shutdown logic 60, and it communicates with the shutdown coil 32a of solenoid 32 and the minimum flow coil 28a of solenoid 28. The cross-engine inhibit logic 70 serves to detect when either the shutdown coil 32a or minimum flow coil 28a has been energized, and provides a corresponding discrete output signal to each channel of the opposite engine's ECU. Channel B has an identical cross-engine inhibit logic arrangement.

[00049] Referring to Fig. 7, there is illustrated a schematic diagram of an alternate embodiment of the two Analog Overspeed Limiter Lanes of Channel A. This circuit provides a more precise test of the derivative path in Lane 1, as compared to the software test interfaces of Fig. 4. Channel B has an identical arrangement.

[00050] Although the subject invention has been described with respect to preferred embodiments, those skilled in the art will readily appreciate that changes and modifications may be made thereto without departing from the spirit and scope of the subject invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A control system for a turboshaft engine comprising:
 - a) means for providing a desired minimum fuel flow to the engine when an overspeed condition is detected and when the engine is operating in a first operating range; and
 - b) means for shutting off fuel flow to the engine when an overspeed condition is detected and the engine is operating in a second operating range.
2. A control system as recited in claim 1, wherein in the first operating range the engine is operating at a relatively low altitude and in the second operating range the engine is operating at a relatively high altitude.
3. A control system as recited in claim 2, wherein the relatively low altitude includes 0 to 10,000 feet above sea level and the relatively high altitude exceeds 10,000 feet above sea level.
4. A control system as recited in claim 1, wherein an overspeed condition is detected along two different control logic paths, a first logic path which includes derivative and non-derivative control logic and a second logic path which includes non-derivative logic.
5. A control system as recited in claim 4, wherein the non-derivative logic includes proportional logic.

6. A control system as recited in claim 1, further comprising a hardware latch having reset logic associated therewith.
7. A control system as recited in claim 1, further comprising software test interfaces for testing the performance of the control system.
8. A control system as recited in claim 1, wherein the means for providing a desired minimum fuel flow to the engine when an overspeed condition is detected includes a first solenoid valve and the means for shutting off fuel flow to the engine when an overspeed condition is detected includes a second solenoid valve.
9. A control system as recited in claim 1, wherein an overspeed condition is detected based on at least one of a power turbine speed signal, a gas generator speed signal and main rotor speed signal.
10. A control system as recited in claim 1, wherein the system is a dual channel system having an interchannel communication means for ensuring that a fault in one channel of the system will not shut down the control system.
11. A control system as recited in claim 1, wherein an overspeed condition is detected based on at least one of a power turbine speed signal, a gas generator speed signal and main rotor speed signal.

12. A control system for a turboshaft engine comprising means for shutting off fuel flow to the engine when an overspeed condition is detected, wherein the overspeed condition is detected by first and second control logic paths, the first path including a derivative path and a non-derivative path and the second path including a non-derivative path.

13. A control system as recited in claim 1, further comprising means for disabling the means for shutting off fuel flow to the engine when an overspeed condition when the engine is operating below an altitude of 10,000.

14. A control system for a turboshaft engine comprising:

- a) means for proving a minimum fuel flow to the engine when an overspeed condition is detected in a first operating range; and
- b) means for shutting off fuel flow to the engine when an overspeed condition is detected in a second operating range, provided that the overspeed condition is detected along two different engine speed signal paths, including a derivative path and a non-derivative path.

15. A control system as recited in claim 14, wherein in the first operating range the engine is operating at a relatively low altitude and in the second operating range the engine is operating at a relatively high altitude.

16. A control system as recited in claim 15, wherein the relatively low altitude includes 0 to 10,000 feet above sea level and the relatively high altitude exceeds 10,000 feet above sea level.

17. A control system as recited in claim 14, wherein the derivative path include derivative and proportional control logic and the non-derivative path includes proportional logic.

18. A control system as recited in claim 14, further comprising a hardware latch having reset logic associated therewith.

19. A control system as recited in claim 14, further comprising software test interfaces for testing the performance of the control system.

20. A control system as recited in claim 14, wherein the means for providing a desired minimum fuel flow to the engine when an overspeed condition is detected includes a first solenoid valve and the means for shutting off fuel flow to the engine when an overspeed condition is detected includes a second solenoid valve.

21. A control system as recited in claim 14, wherein an overspeed condition is detected based on at least one of a power turbine speed signal, a gas generator speed signal and main rotor speed signal.

22. A control system as recited in claim 14, wherein the system is a dual channel system having an interchannel communication means for ensuring that a fault in one channel of the system will not shut down the control system.

23. A method for limiting turboshaft engine overspeed comprising the steps of:

- a) measuring at least one engine speed parameter;
- b) sensing the altitude at which the engine is operating;
- c) determining whether an overspeed condition exists based on the measured speed parameter using a control system which includes a first logic path having derivative and non-derivative control logic and a second logic path having non-derivative logic;
- d) providing a desired minimum fuel flow to the engine when an overspeed condition is detected by the engine control system when the engine is operating in a first altitude range; and
- e) shutting off fuel flow to the engine when an overspeed condition is detected by the engine control system and the engine is operating in a second operating range.

1/7

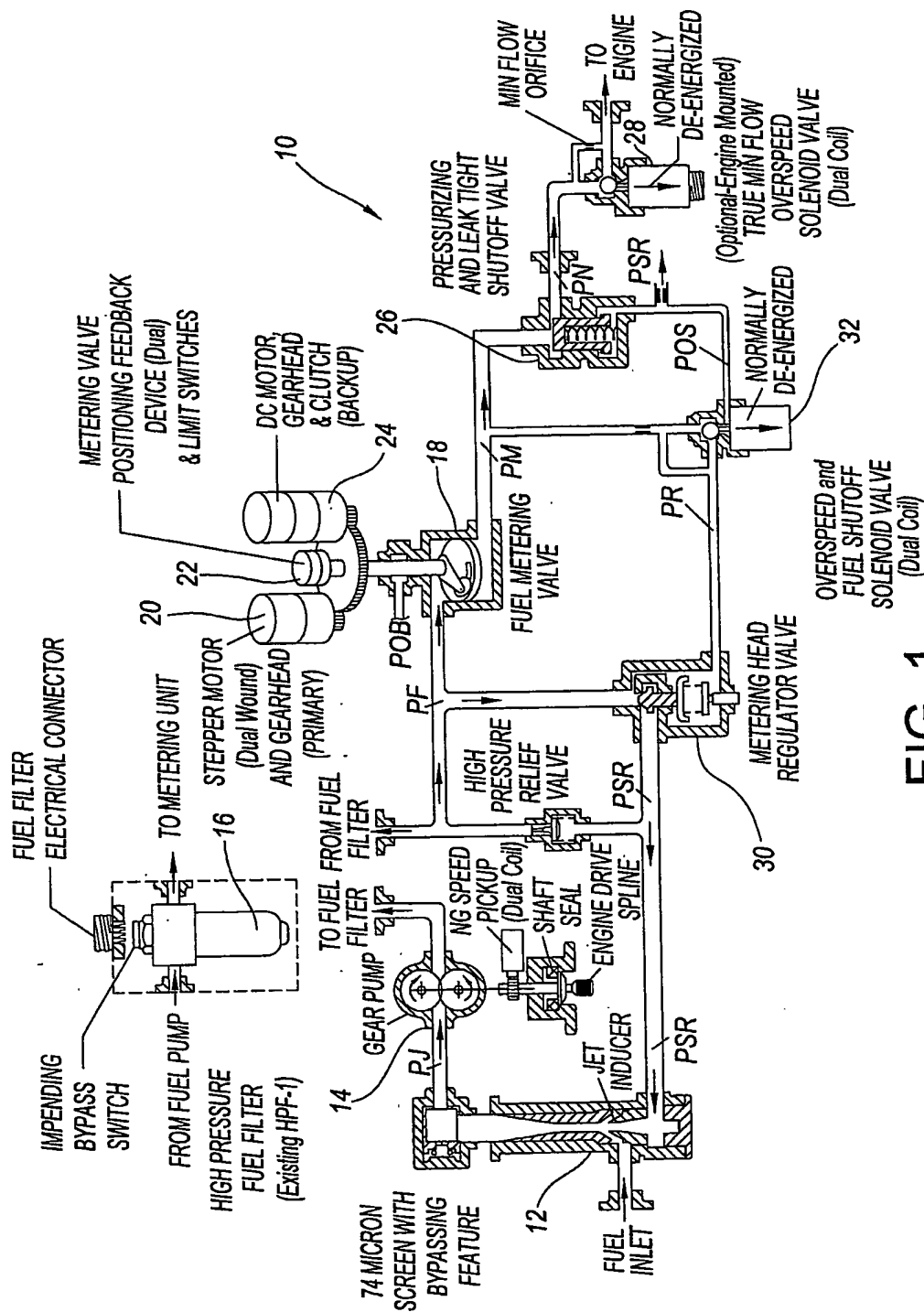


FIG. 1

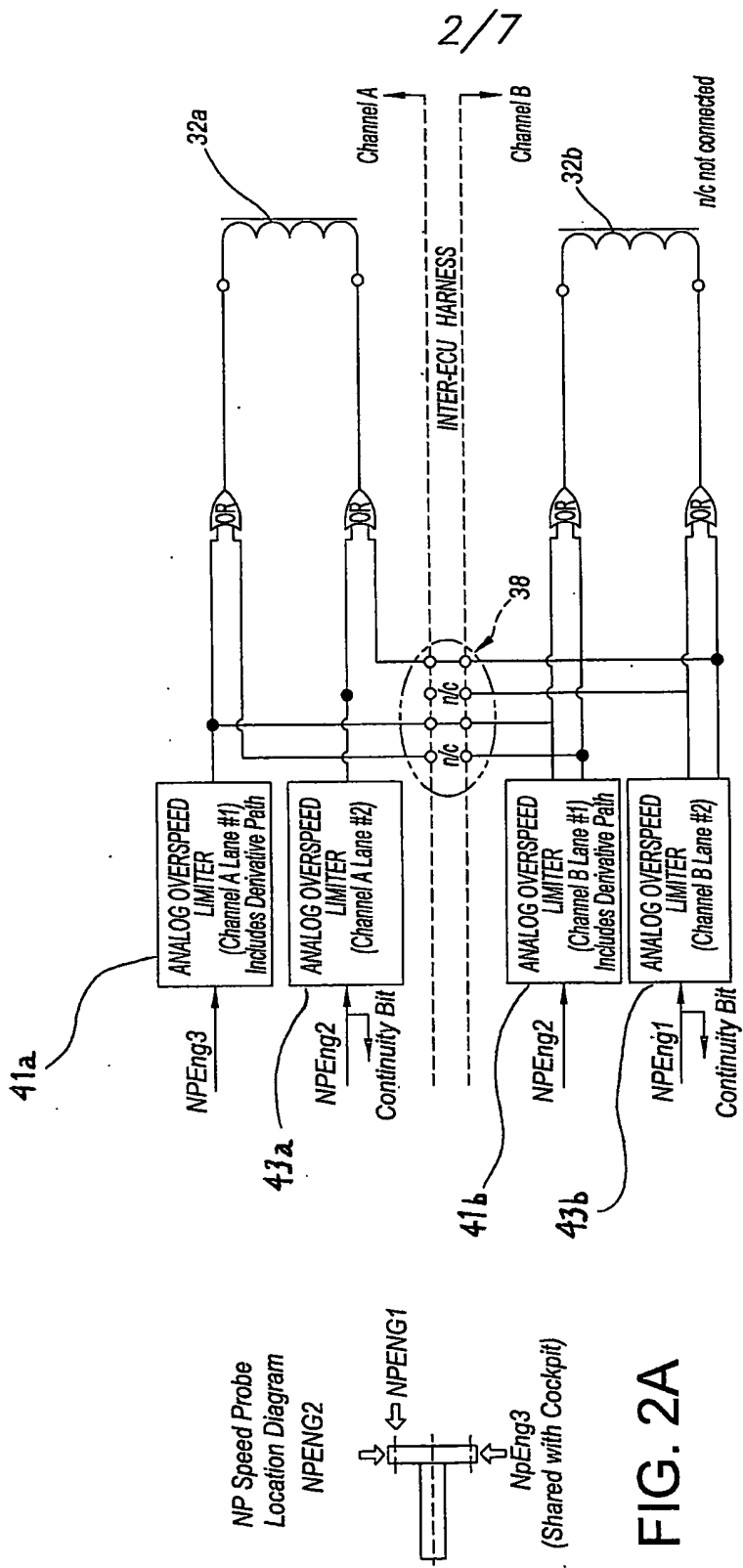


FIG. 2

FIG. 2A

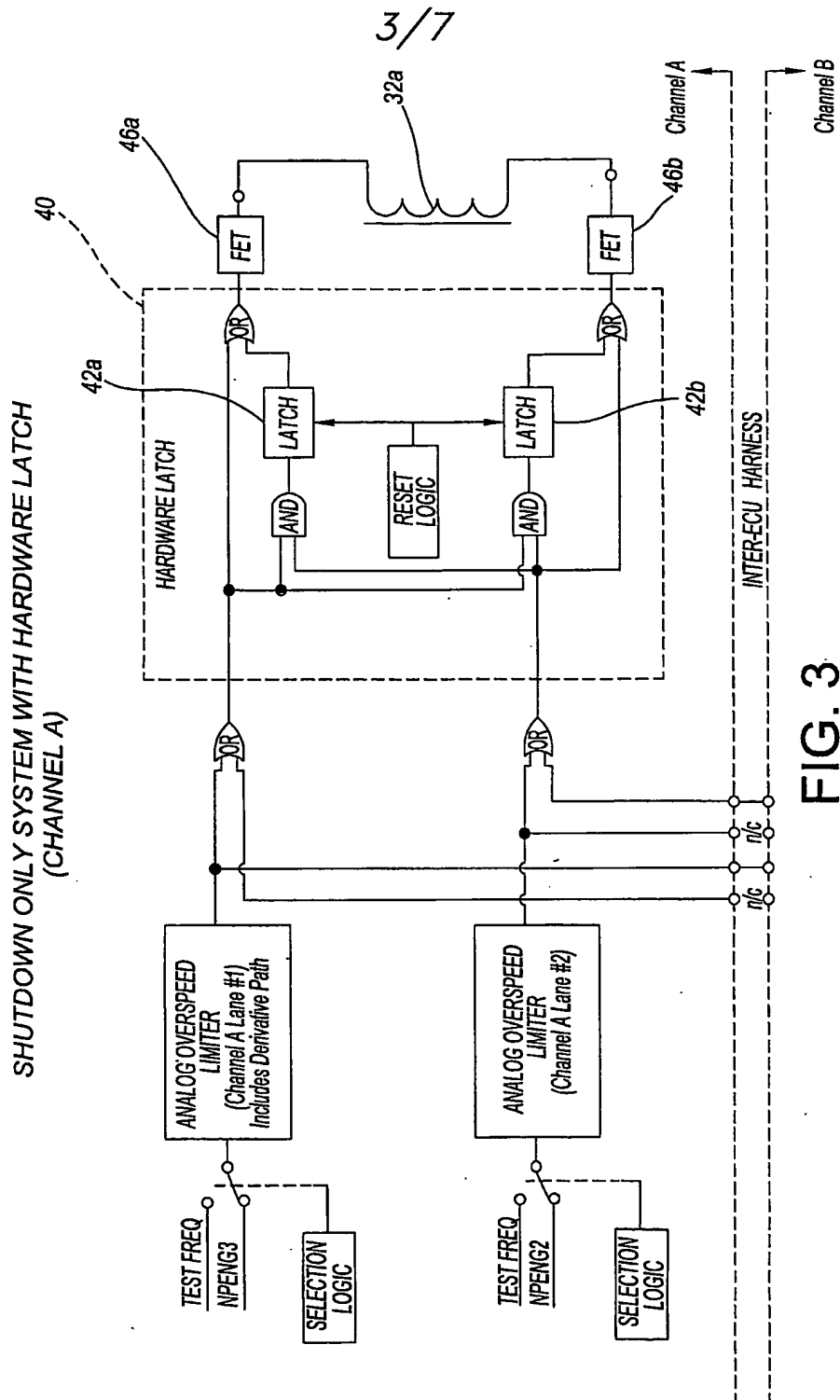


FIG. 3

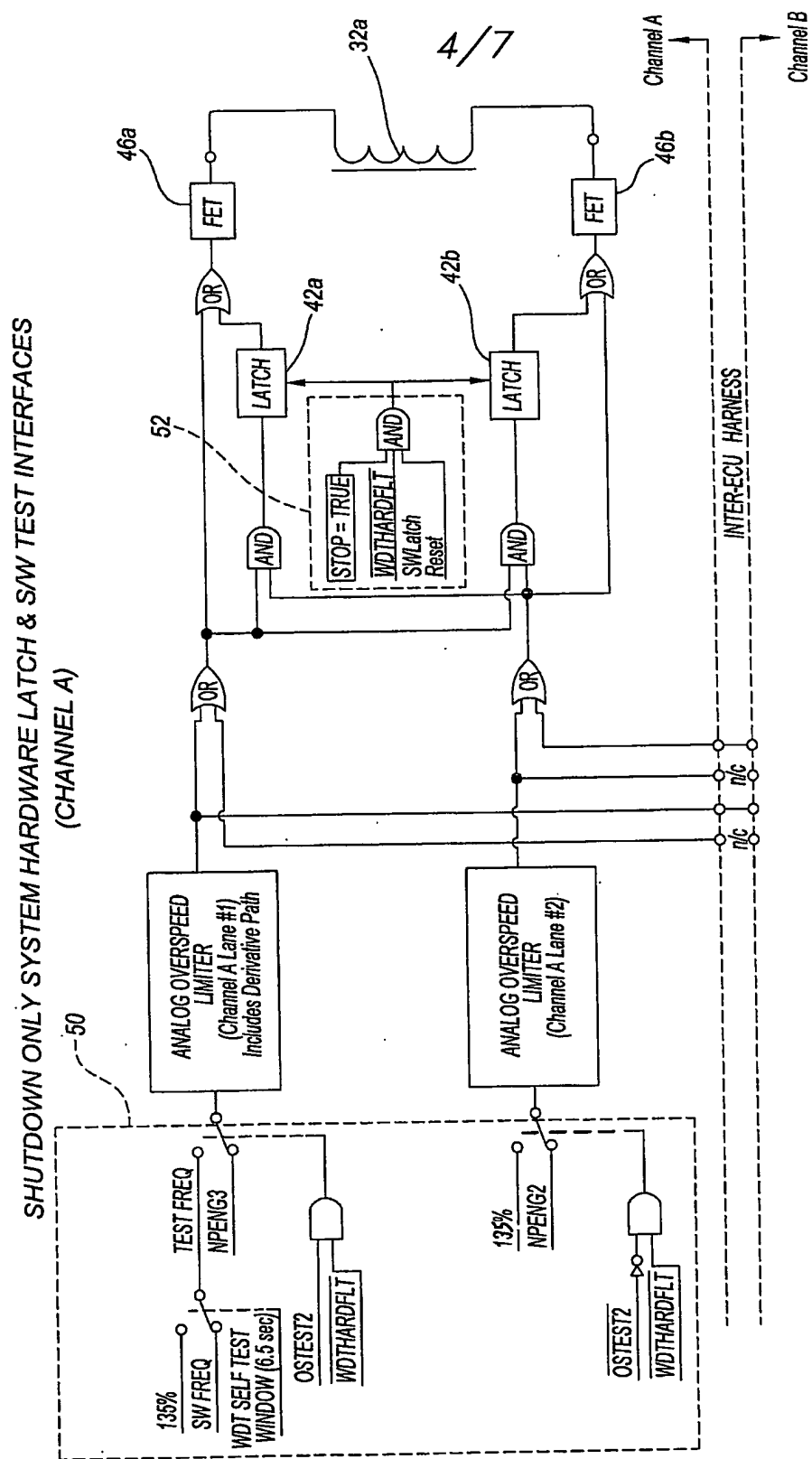


FIG. 4

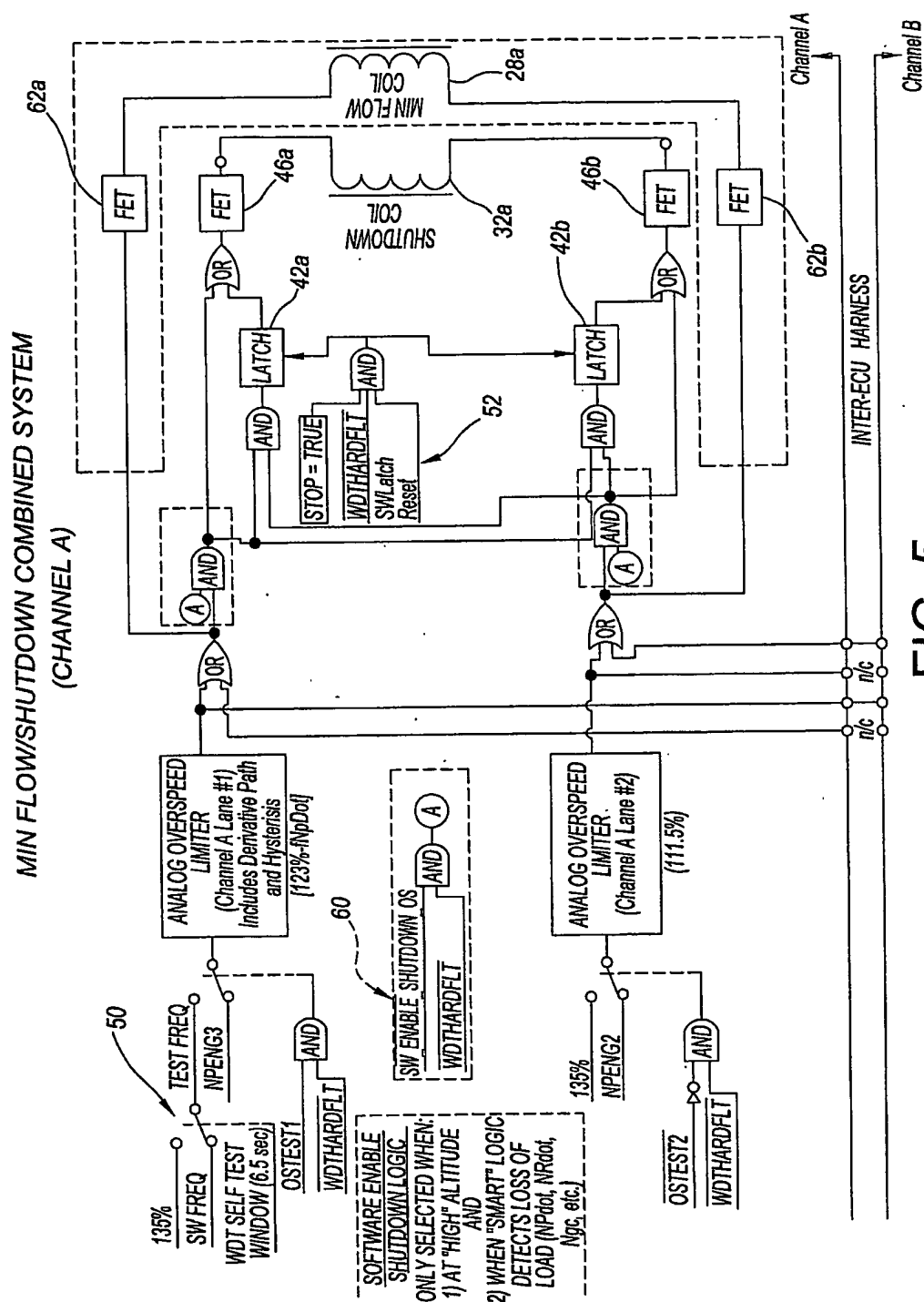


FIG. 5

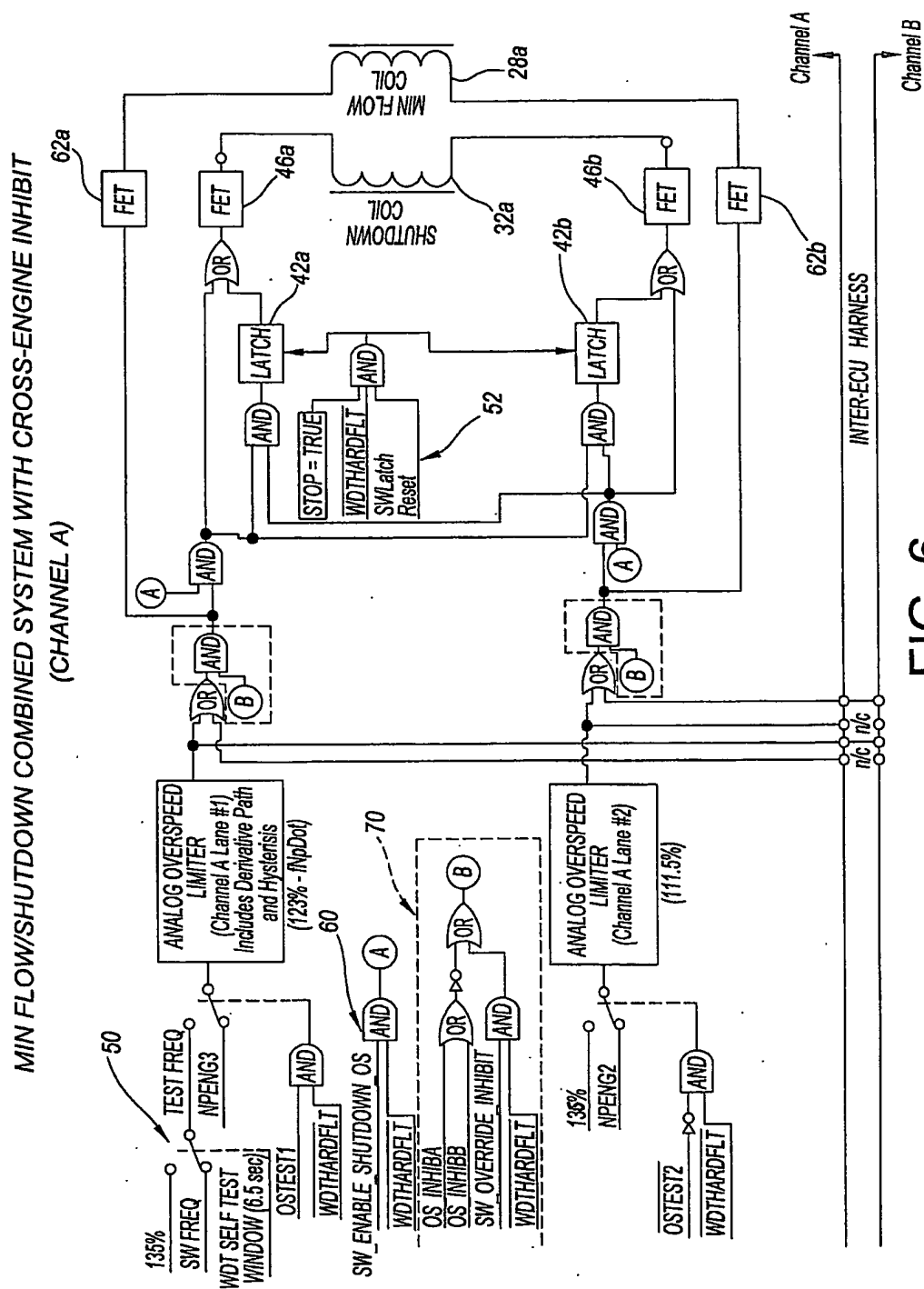


FIG. 6

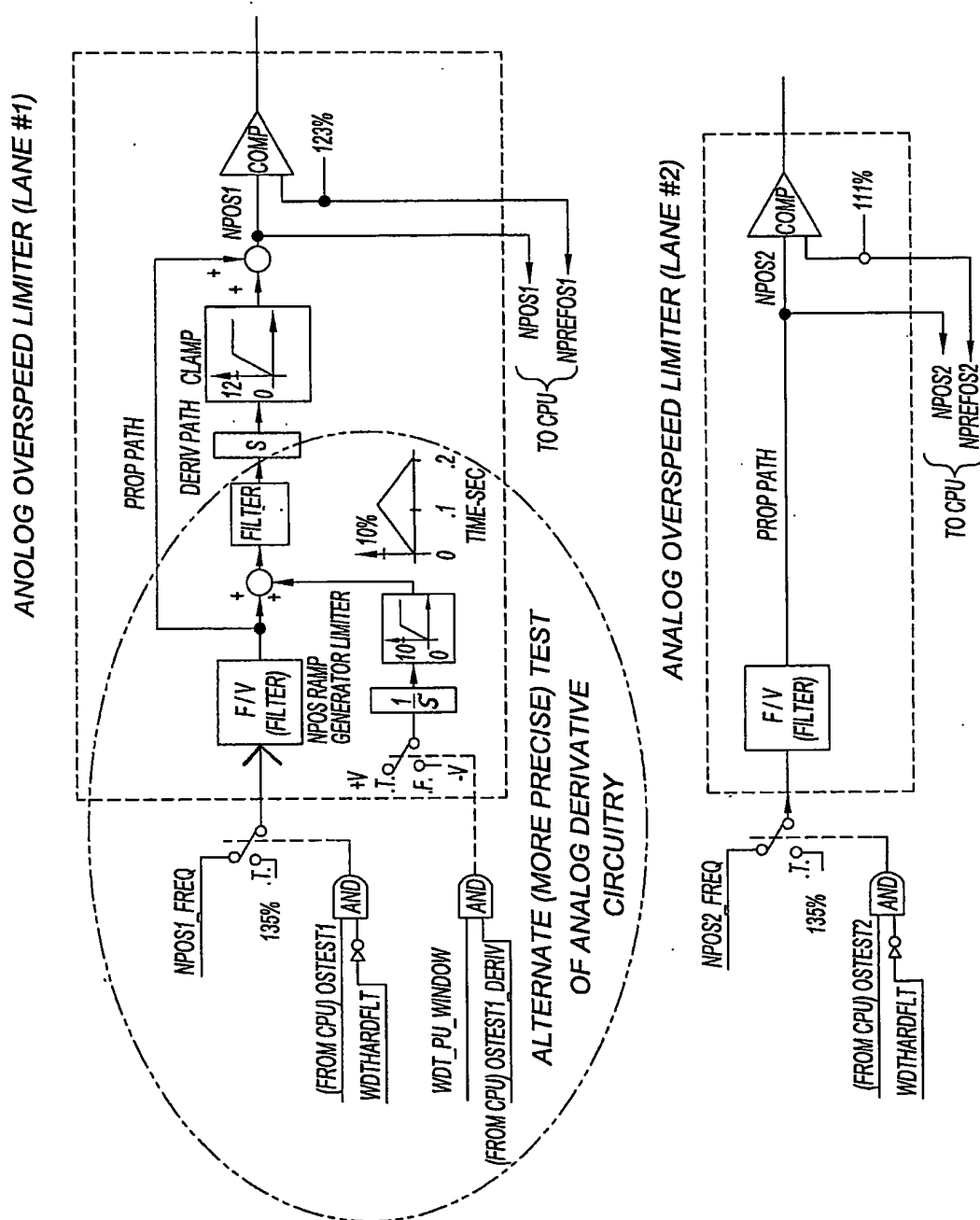


FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/019699

A. CLASSIFICATION OF SUBJECT MATTER IPC 7 F01D21/02 F02C9/28 F02C9/46		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC 7 F01D F02C		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data, PAJ		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 045 955 A (BRANNSTROM ET AL) 6 September 1977 (1977-09-06) column 1, line 14 - column 3, line 39; figure 1	12
X	DE 17 51 821 A1 (LICENTIA PATENT-VERWALTUNGS-GMBH; LICENTIA PATENT-VERWALTUNGS-GMBH, 60) 19 May 1971 (1971-05-19) page 2, line 7 - page 2, line 19	12
X	US 4 454 754 A (ZAGRANSKI ET AL) 19 June 1984 (1984-06-19) column 1, line 55 - column 3, line 10; figure 1	12
A	----- -/-	4-6,9, 11,17-20
<div style="display: flex; justify-content: space-between;"> <input checked="" type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex. </div>		
<div style="display: flex;"> <div style="flex: 1;"> <p>* Special categories of cited documents :</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="flex: 1;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p> </div> </div>		
Date of the actual completion of the international search <div style="text-align: center; font-weight: bold;">23 September 2005</div>		Date of mailing of the international search report <div style="text-align: center; font-weight: bold;">30/09/2005</div>
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016		Authorized officer <div style="text-align: center; font-weight: bold;">Rau, G</div>

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/019699

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 087 978 A (ROLLS ROYCE LTD) 3 June 1982 (1982-06-03) page 1, line 21 - page 1, line 44 page 2, line 32 - page 2, line 73; figure 1	1,14,23
A	US 4 578 945 A (PECK ET AL) 1 April 1986 (1986-04-01) cited in the application column 3, line 52 - column 4, line 24; figure 2	1
A	EP 1 327 751 A (PRATT & WHITNEY CANADA CORP) 16 July 2003 (2003-07-16) column 7, line 21 - column 8, line 2; figure 3	10,22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2005/019699

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-11,13-23

Based on operating range either minimum fuel flow or
shutting off fuel flow when an overspeed condition is
detected

2. claim: 12

Overspeed detection with two control logic paths

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US2005/019699

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4045955	A	06-09-1977	CH 608860 A5 DE 2635993 A1 GB 1552990 A SE 393160 B SE 7509603 A	31-01-1979 10-03-1977 19-09-1979 02-05-1977 01-03-1977
DE 1751821	A1	19-05-1971	NONE	
US 4454754	A	19-06-1984	NONE	
GB 2087978	A	03-06-1982	NONE	
US 4578945	A	01-04-1986	NONE	
EP 1327751	A	16-07-2003	NONE	